

# VHR seismic imaging of displacement along an active off-shore fault system of the Adriatic foreland

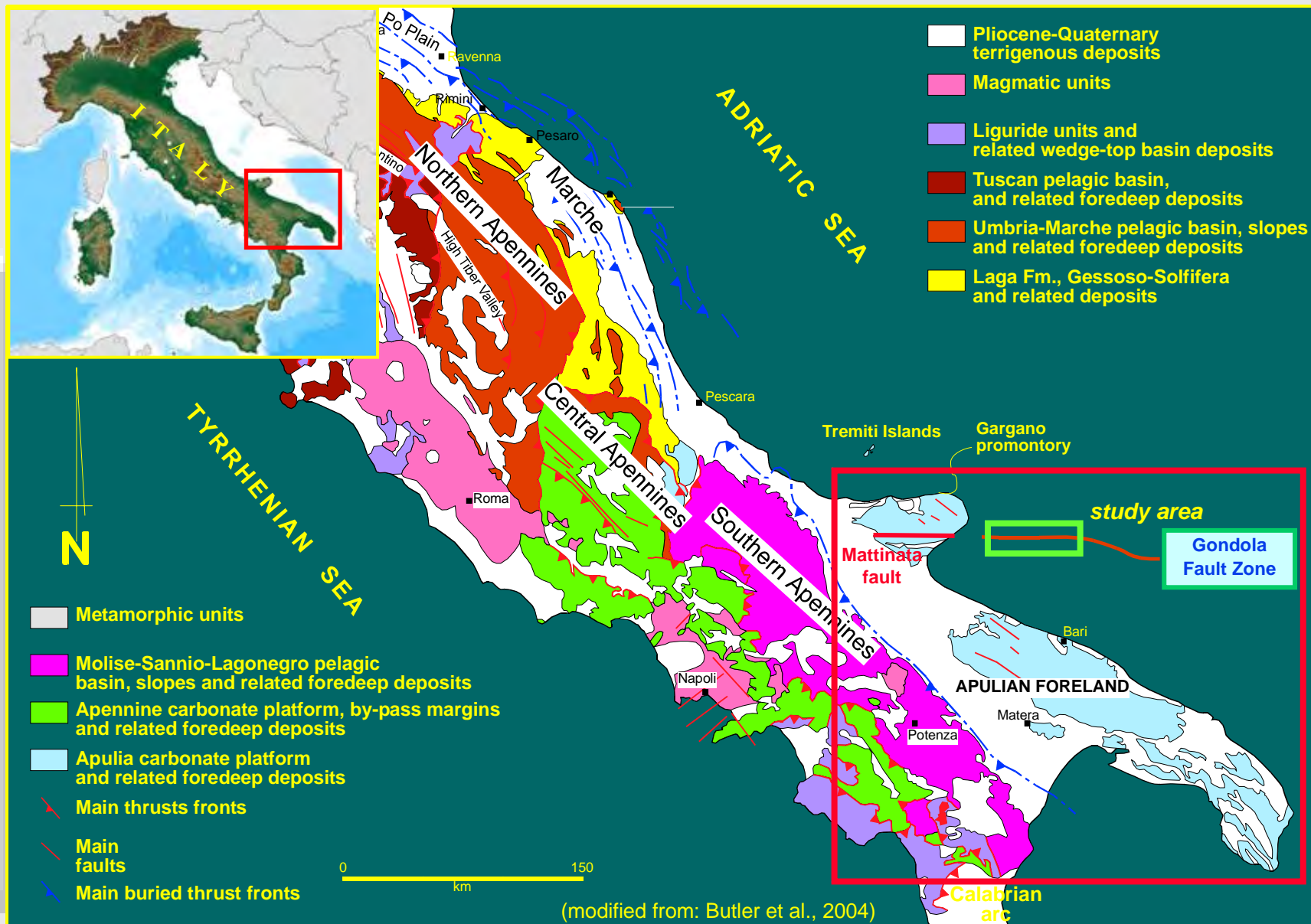
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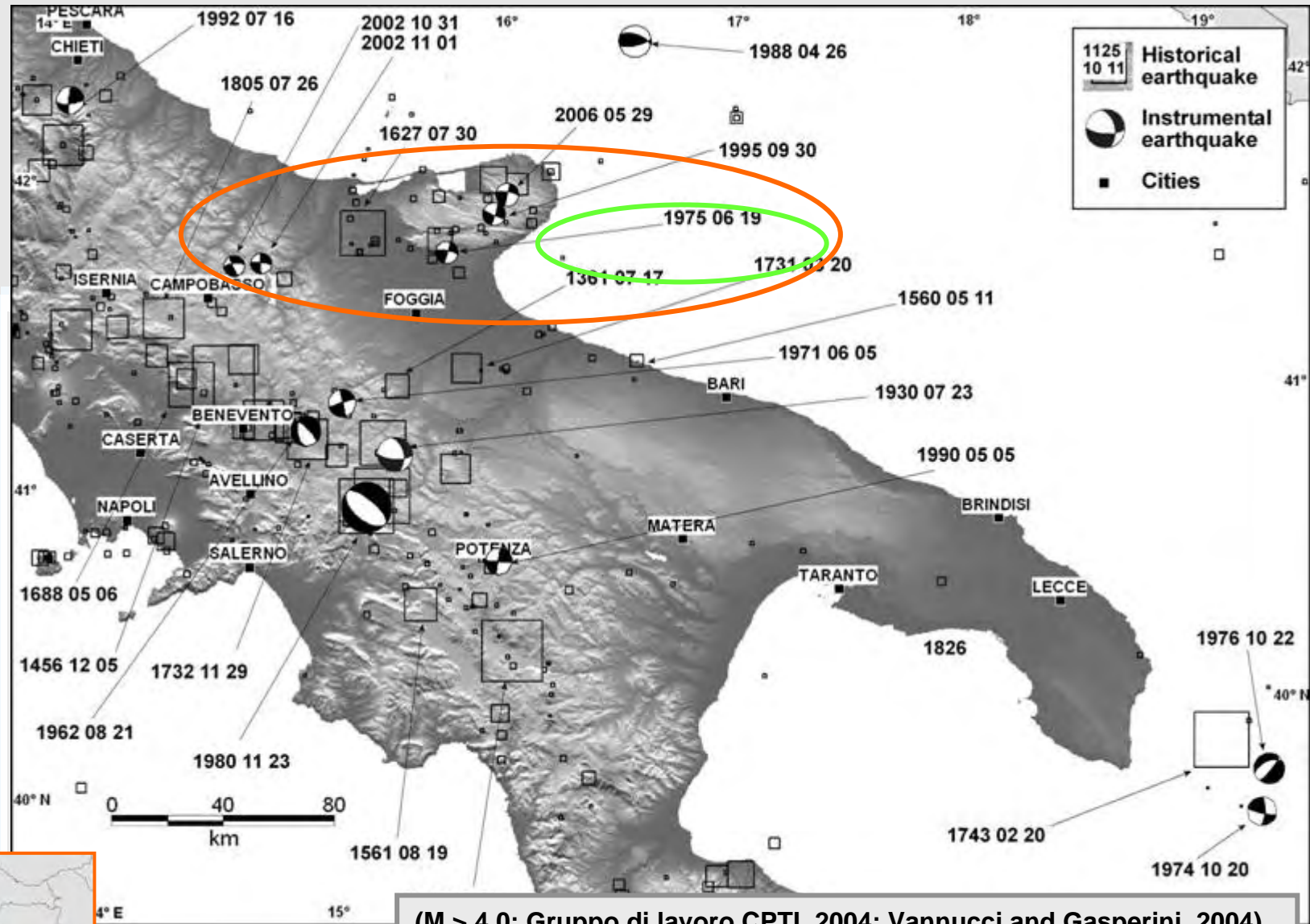
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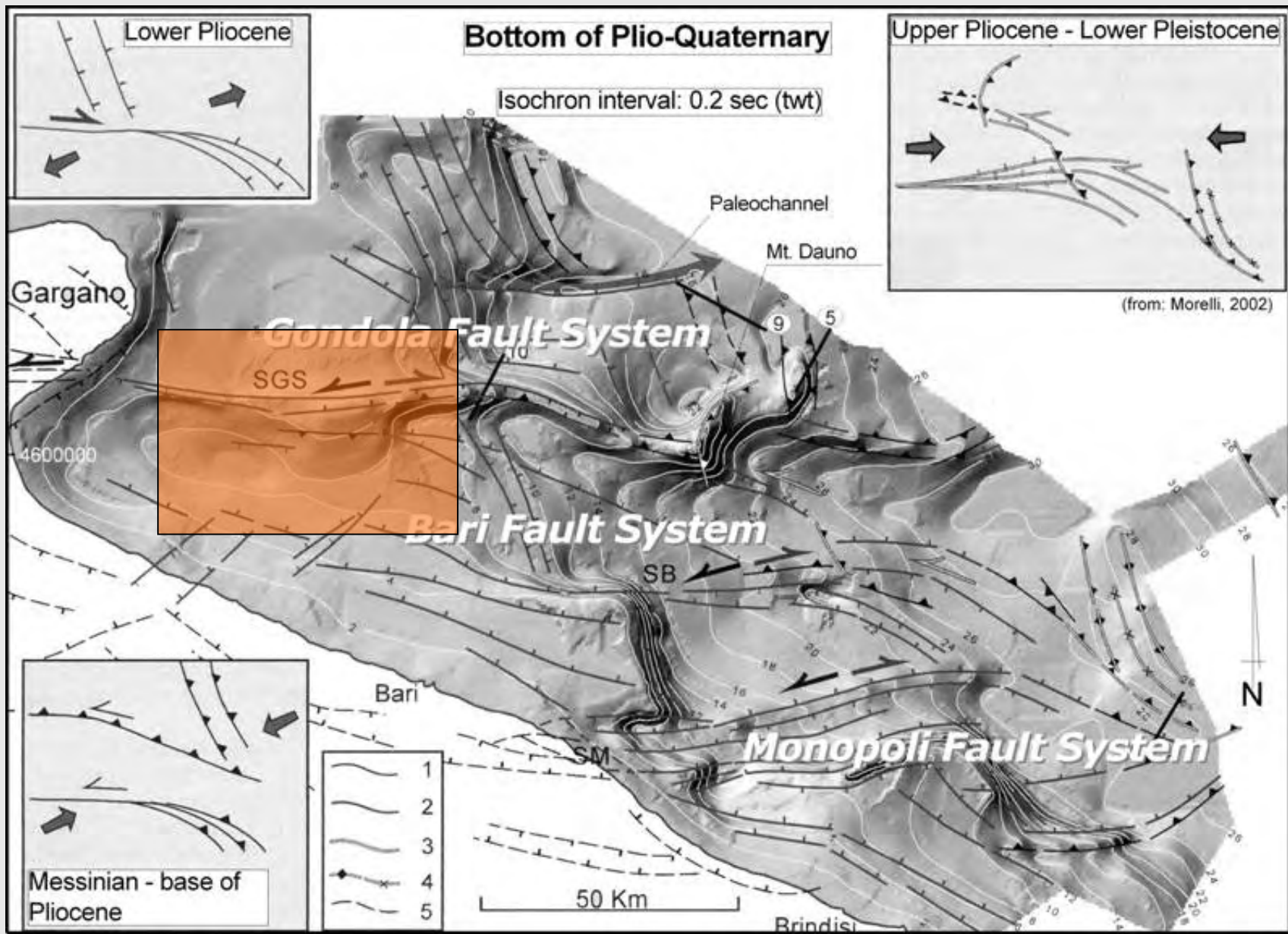
## Study area and regional geological setting



( $M > 4.0$ ; Gruppo di lavoro CPTI, 2004; Vannucci and Gasperini, 2004). The size of the square symbols is proportional to an equivalent magnitude derived from intensity data.

## Historical and instrumental earthquakes of the Central and Southern Apennines

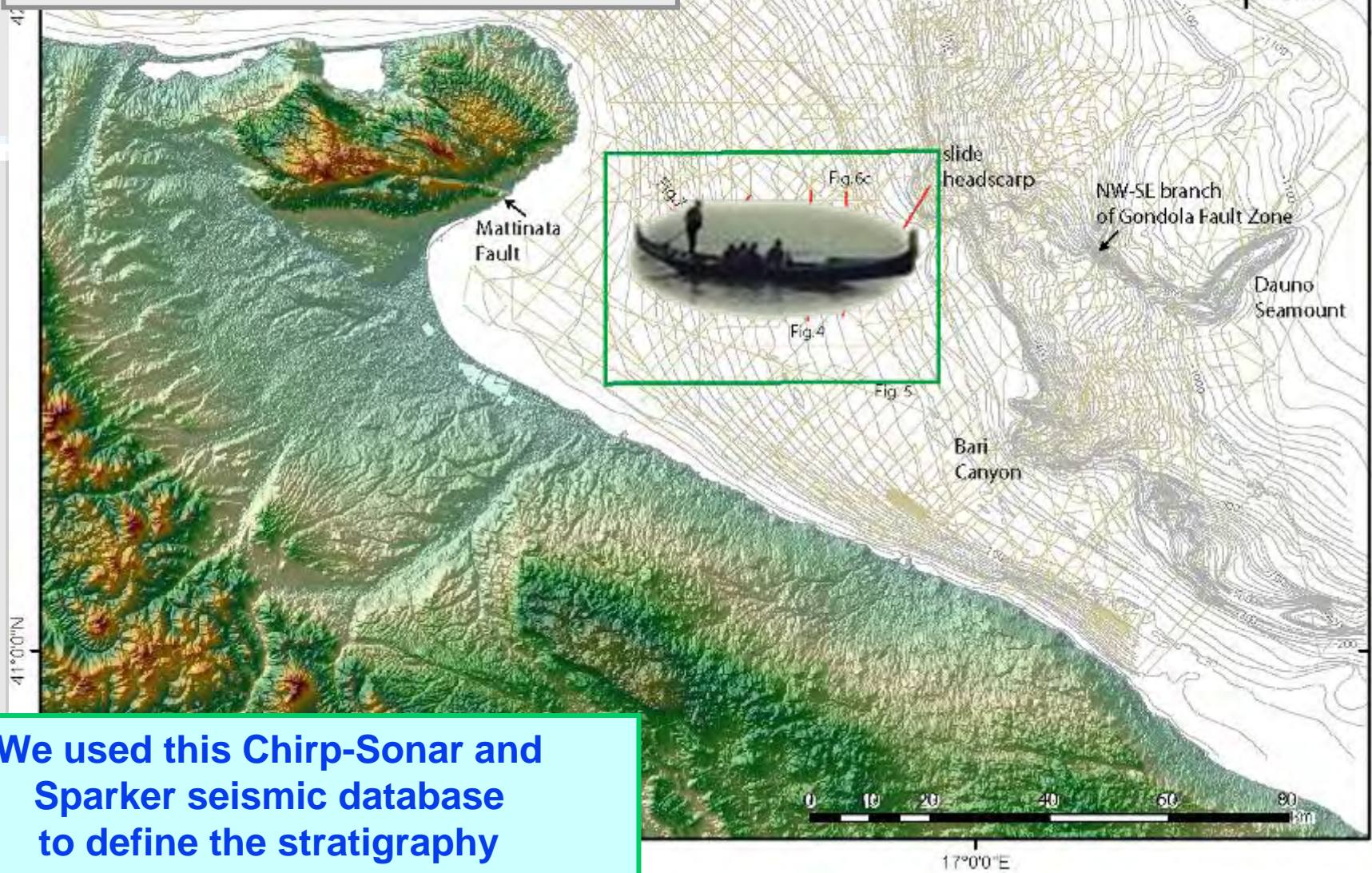




**Structural setting of the Gondola Fault Zone and nearby areas**  
based on high-penetration/low-resolution seismic data



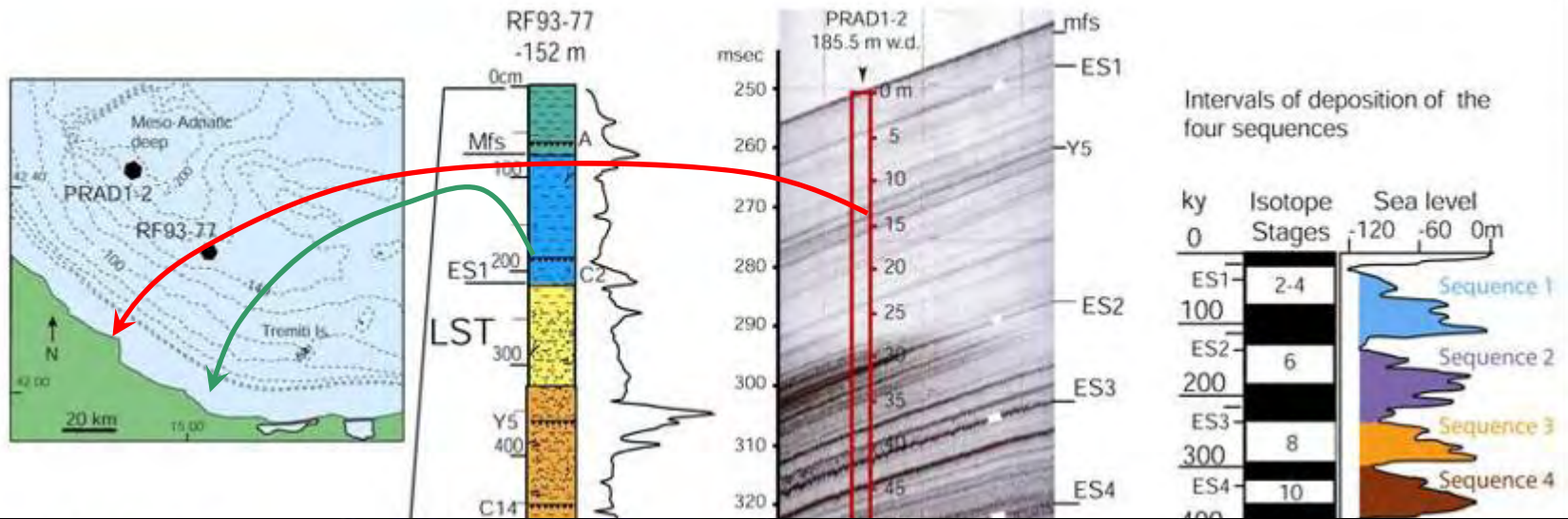
**Bathymetry (grey lines):**  
depth < 100 m, isobaths every 5 m;  
depth between 100 and 200 m, isobaths every 10 m;  
depth > 200 m, isobaths every 20 m.



**We used this Chirp-Sonar and  
Sparker seismic database  
to define the stratigraphy  
of Late Quaternary deposits  
and the pattern of active deformation**

***High-resolution seismic database***

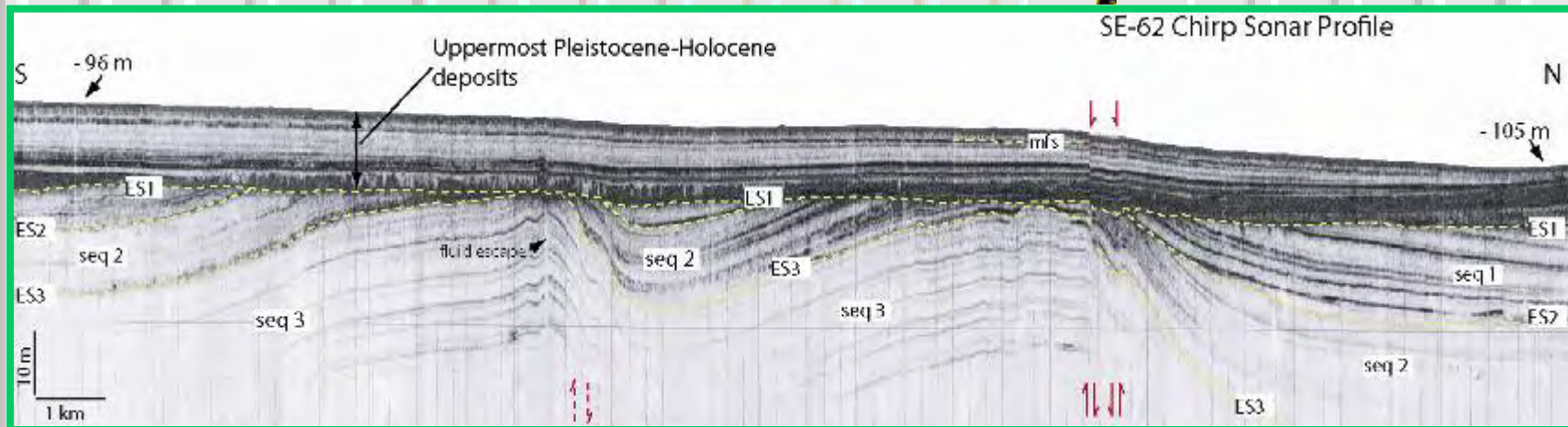
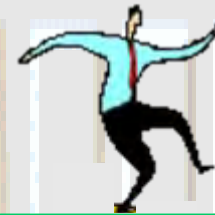




Sequence	Oxygen Isotope Stage	Age (ka)	Erosional Surface
		Present-day – 20/30	
Sequence 1	OIS 2-6	20/30 – 130/140	← ES1
Sequence 2	OIS 6-8	130/140 – 230/250	← ES2
Sequence 3	OIS 8-10	230/250 – 330/350	← ES3
Sequence 4	OIS 10-12	330/350 – 430/450	← ES4
			ES5

***Depositional sequences and time lapses***

**All along the E-W segment of the Gondola Fault Zone, late Quaternary deposits appear folded and faulted (locally up to seafloor).**

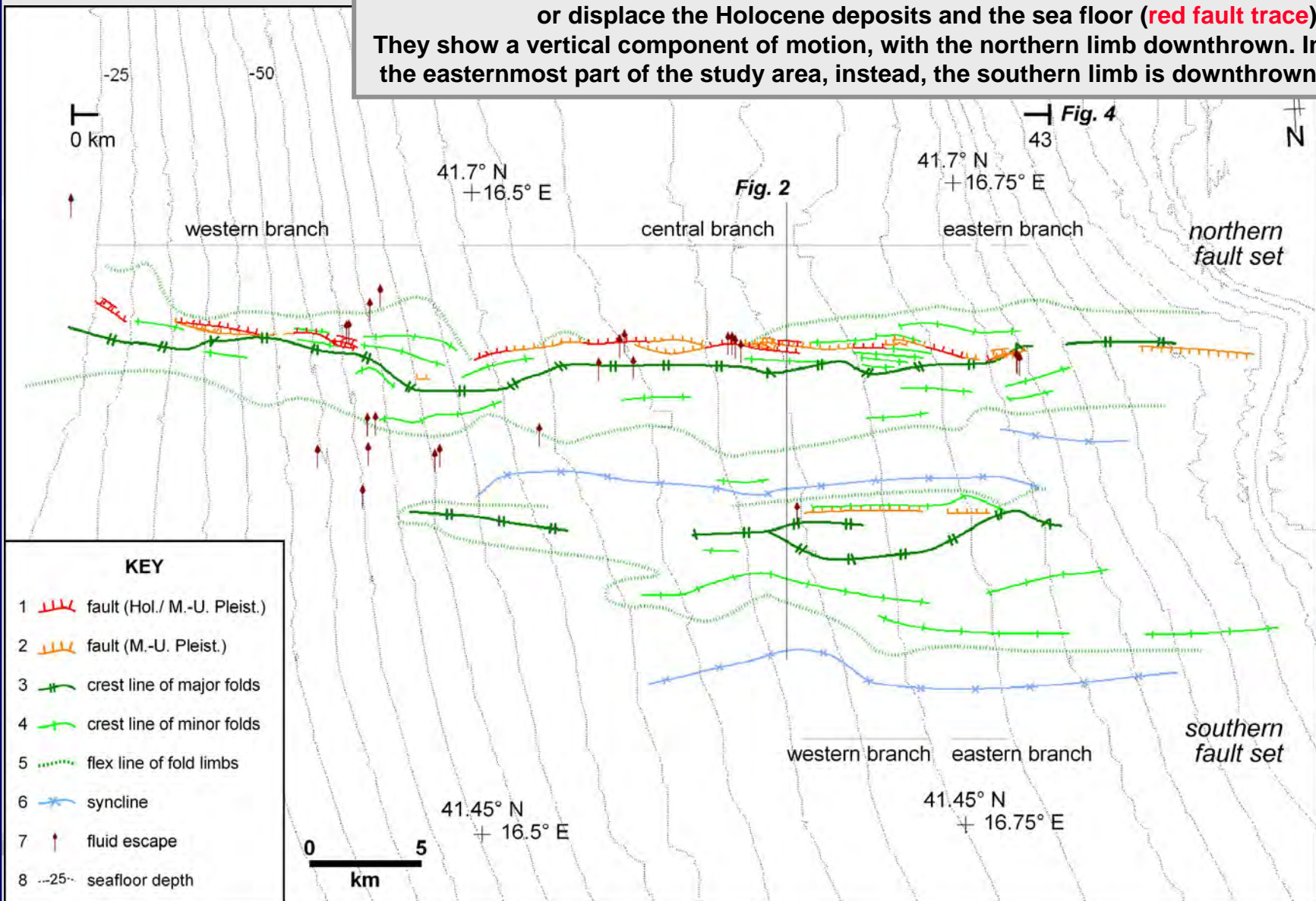


mfs = 5.5 ka maximum flooding surface

**Key stratigraphic and structural features of the study area**



Two **major anticlines** affected by a fault system can be identified. The faults may appear sealed by the ES1 surface (**orange fault trace**) or displace the Holocene deposits and the sea floor (**red fault trace**). They show a vertical component of motion, with the northern limb downthrown. In the easternmost part of the study area, instead, the southern limb is downthrown.



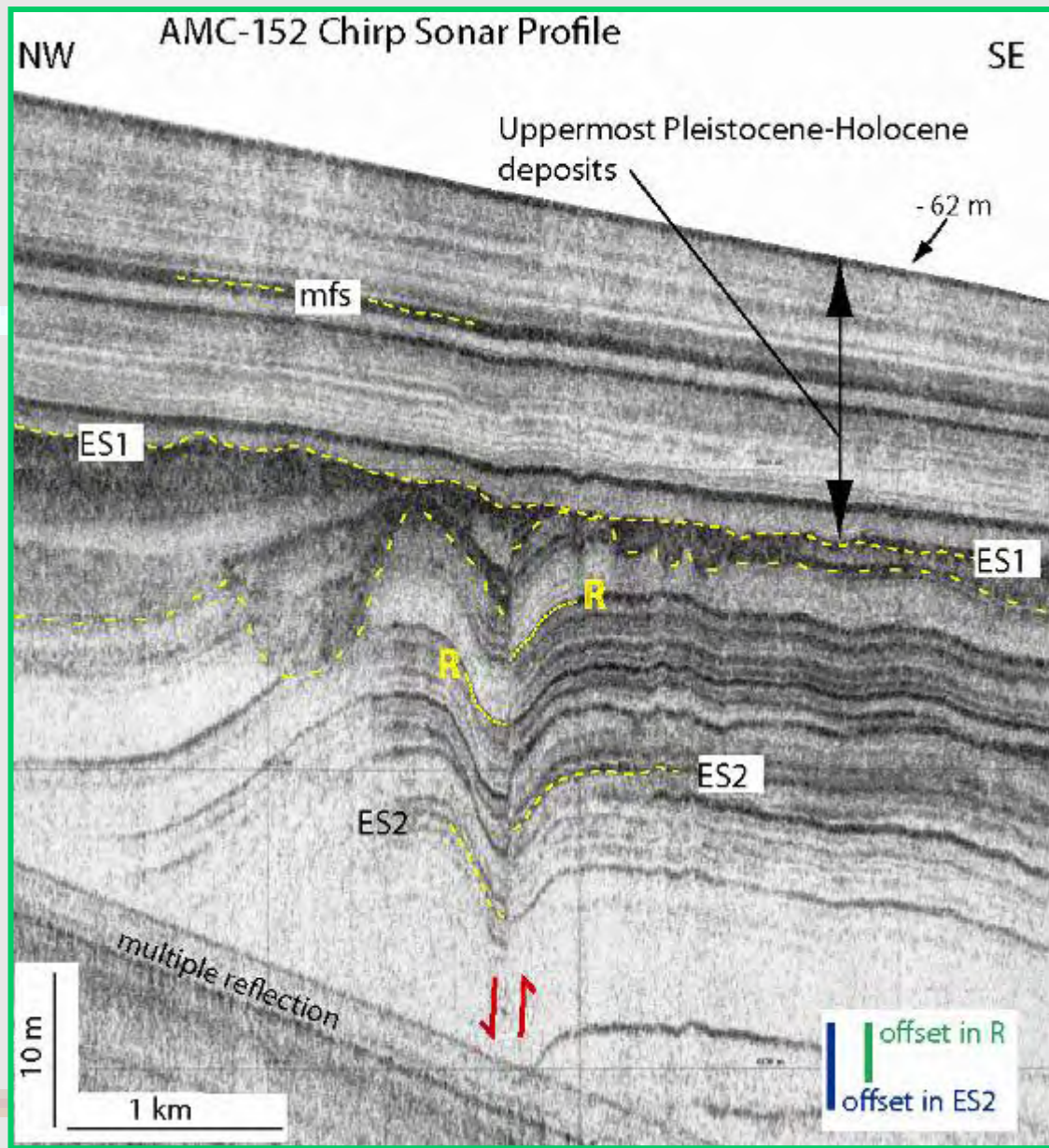
## Structural map of the Gondola Fault Zone



**Evidence of a secondary fold on the downthrown (northern) limb of the northern fault.**

**We interpreted this kind of features as the expression of an unresolved strike-slip component of motion.**

**Also notice the variable offset of reflectors along the fault plane.**



***An example of Chirp Sonar seismic profile***

**The entire deformation pattern of the Gondola Fault Zone suggests a significant strike-slip component of motion. Also at local scale, near-fault hanging-wall deformation suggests that the observed faults may well slip with an unresolved lateral component of motion.**

**The overall geometry, formed by fault segments with minor vertical separation, connected by non-faulted sections where the anticline is better developed, supports dextral slip.**

**Unfortunately, our data did not allow us to estimate the horizontal displacement.**





**We further integrated our studies with the analysis of new and closely-spaced (ca. 500-600 m) VHR seismic lines acquired during a 2006 cruise. The density of the data set allowed us to focus on the distribution in space and time of the**

**vertical displacement**

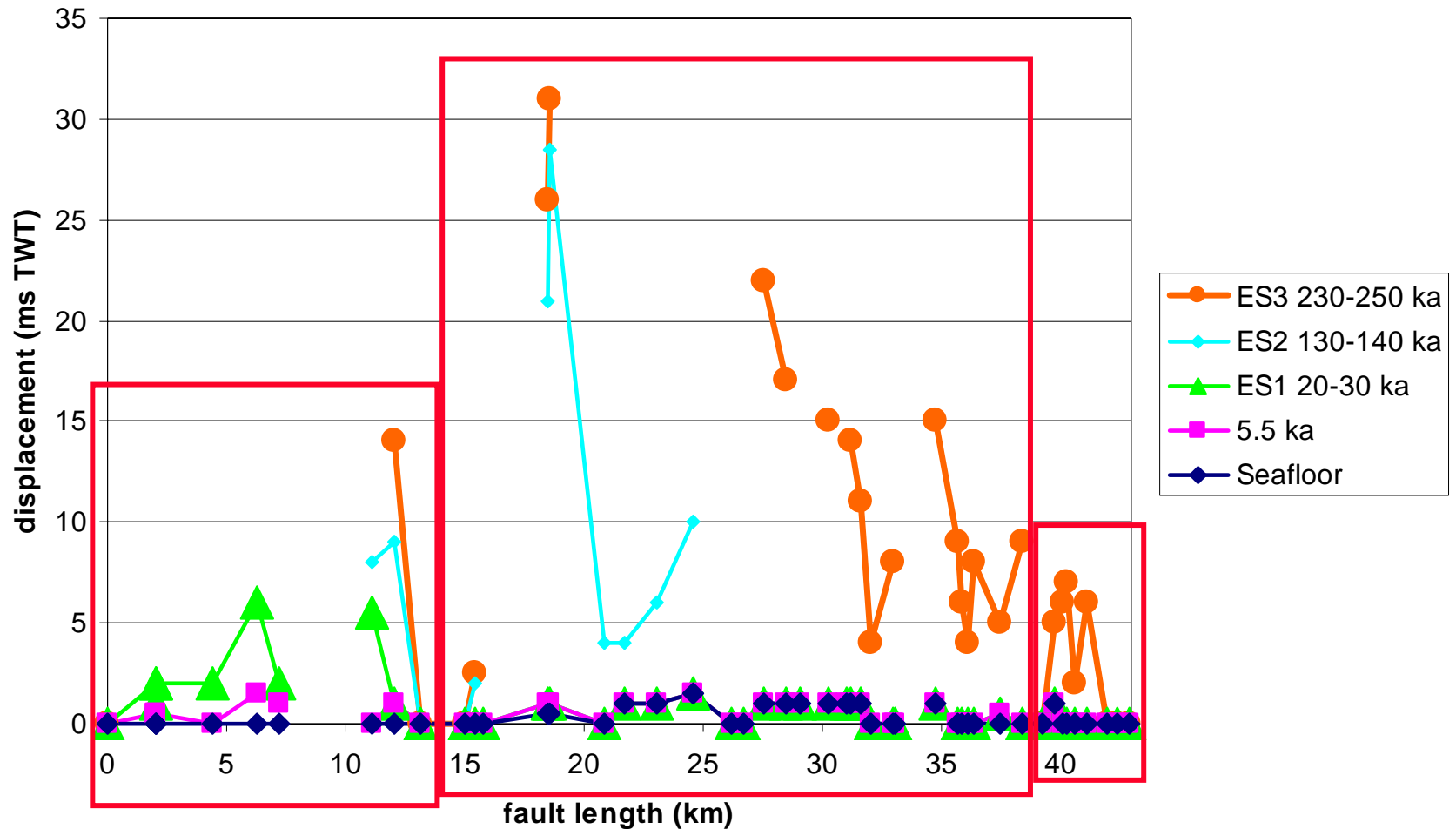
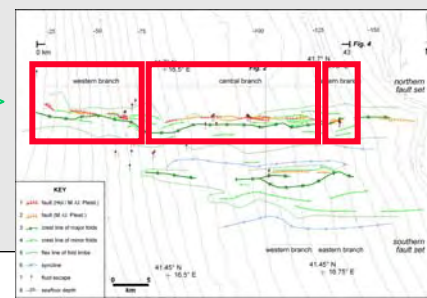
**measured on the fault planes dissecting shallow deposits up to the seafloor along the E-W branch of the Gondola Fault Zone.**



1 ms TWT = ca. 0.75 m

W

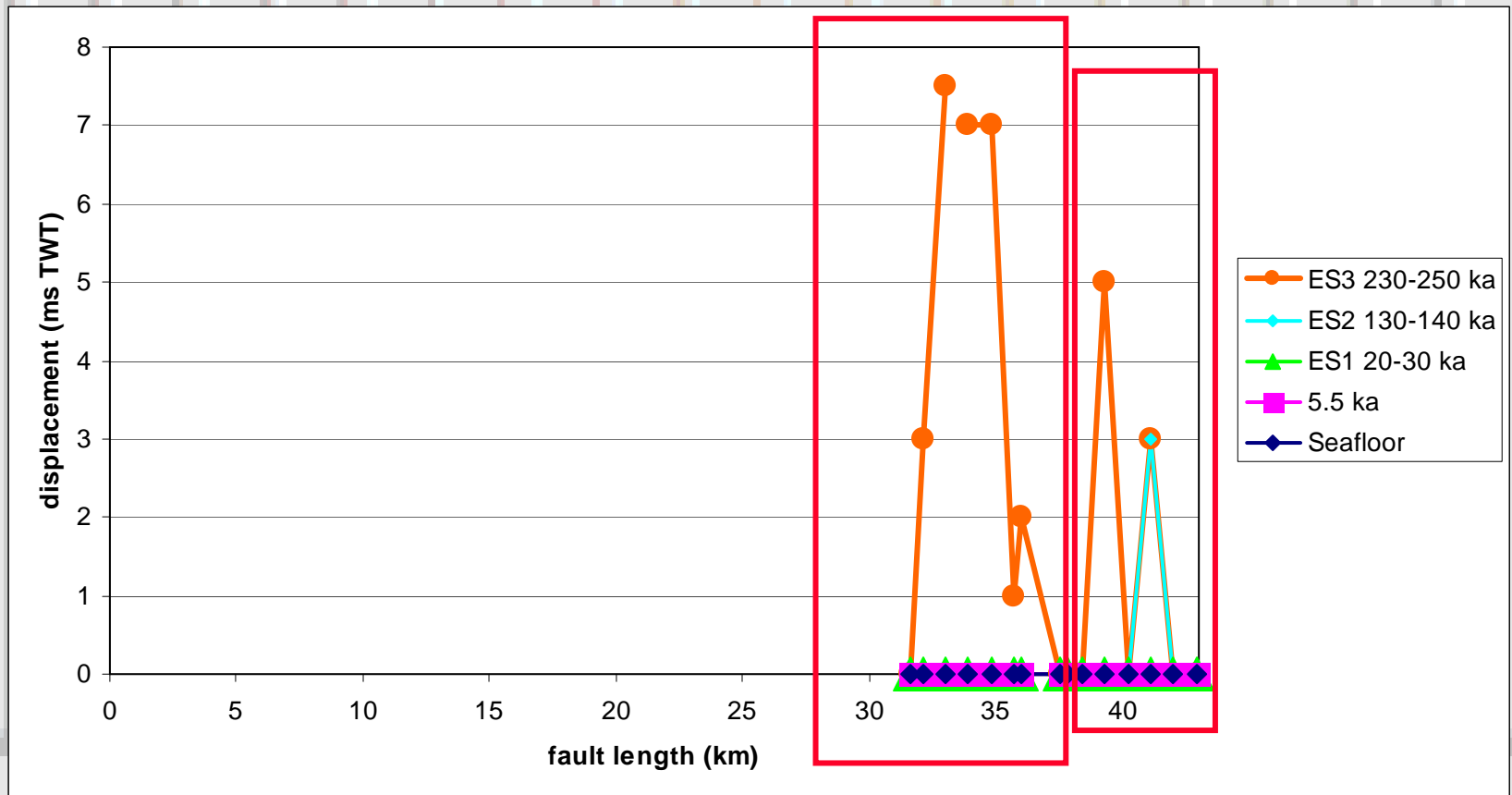
E



**Vertical displacement along the northern fault set**



1 ms TWT = ca. 0.75 m

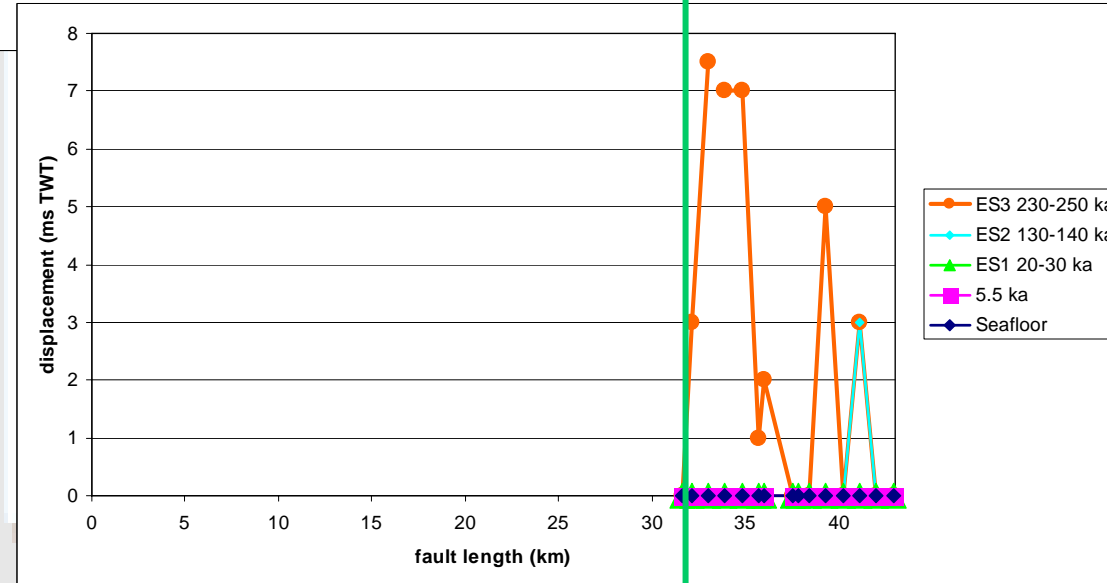
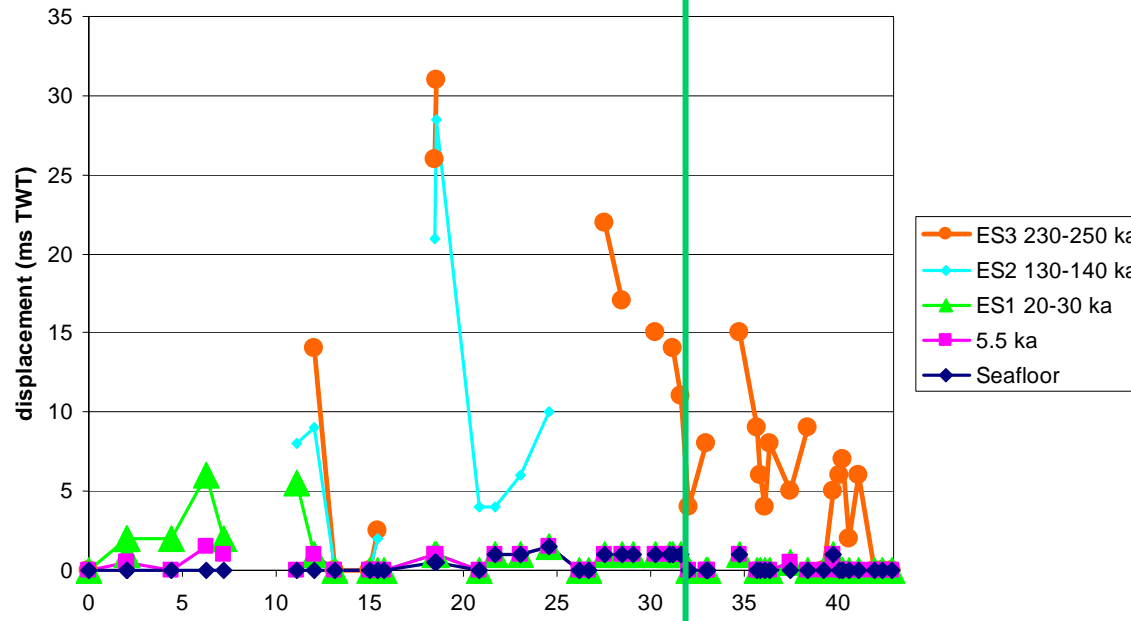


**Vertical displacement along the southern fault set**

W

E

different  
vertical  
scales



1 ms TWT = ca. 0.75 m

Comparison



$D$  = cumulative values of displacement  
 $\Delta D$  = differential values of displacement

	Northern fault set (from W to E)			Marker surface (mean age)	Southern fault set (from W to E)	
Branch length (km)	11.60	23.65	2.02		4.90	2.70
D (ms TWT)	14	31	7	ES3 (240 ka)	7.5	5
D (m)	10.5	23.25	5.25		5.65	3.75
Slip rate (mm/a)	0.04	0.10	0.02		0.02	0.02
D (ms TWT)	9	28.5	-	ES2 (135 ka)	-	3
D (m)	6.75	21.38	-		-	2.25
Slip rate (mm/a)	0.05	0.16	-		-	0.02
D (ms TWT)	6	1.5	1	ES1 (25 ka)	0	0
D (m)	4.5	1.13	0.75		0	0
Slip rate (mm/a)	0.18	0.05	0.03		0	0

	Northern fault set (from W to E)			Time interval (mean age)	Southern fault set (from W to E)	
Branch length (km)	11.60	23.65	2.02		4.90	2.70
$\Delta D$ (m)	3.75	1.87	4.50	ES3-ES2 (105 ka)	5.65	1.50
$\Delta$ Slip rate (mm/a)	0.04	0.02	0.04		0.05	0.01
$\Delta D$ (m)	2.25	20.25	-	ES2-ES1 (105 ka)	-	2.25
$\Delta$ Slip rate (mm/a)	0.02	0.19	-		-	0.02
$\Delta D$ (m)	4.5	1.13	0.75	ES1-present (25 ka)	0	0
$\Delta$ Slip rate (mm/a)	0.18	0.05	0.03		0	0

**Vertical slip rates**

- The bell-shaped distribution of the displacements suggests a long-term behavior of the GFZ as a single structure.
- However, the irregular displacement distribution on the different branches and the related slip rates, i.e. the evidence of distinct deformation histories, implies that this single structure is composed of fault segments that can slip independently.
- A long-term homogeneous behavior of the GFZ, operating as a single structure, is also supported by the evidence of comparable and low values within a limited range (0 - 0.18 mm/a) for all branches.



- Apart from the differentiated deformation rates, our data are strikingly similar to those acquired with comparable methods along well-known, major seismogenic fault systems, e.g. along the North Anatolian Fault (Polonia et al., 2004) or in the Panama Canal (Pratt et al., 2003).

- Moreover, the vertical slip rates here presented are comparable with those calculated from surface geological data along the Mattinata Fault (0.2-0.3 mm/a; Tondi et al., 2005), a known seismogenic source sharing the same tectonic environment of the GFZ.

- Surface evidence thus suggests that the GFZ as well may be seismogenic. Defining the structural relationships between its shallower and deeper portions, up to typical hypocentral depth, is therefore fundamental for a correct assessment of its seismogenic potential.







***Thank you!***